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SPECIFICATION FOR TROLLEY AND CONTACT WIRE FOR ELECTRIC TRACTION

(First Revision)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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April 1987

Indian Standard

SPECIFICATION FOR TROLLEY AND CONTACT WIRE FOR ELECTRIC TRACTION

(First Revision)

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Indian Standard

SPECIFICATION FOR TROLLEY AND CONTACT WIRE FOR ELECTRIC TRACTION

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 29 July 1986, after the draft finalized by Conductors and Accessories for Overhead Lines Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard was first published in 1967. This revision is being undertaken to upgrade many of the requirements and to bring this standard in line with the latest practices in the field.

0.3 In preparing this standarad, assistance has been taken from the following:

BS 23 : 1970 Specification for copper and copper-cadmium trolley and contact wire for electric traction. British Standards Institution.

U. I. C. Code 870-0 (first edition) Technical specification for grooved contact wires. International Union of Railways.

ETI/OHE/42 (11/83) Specification for copper trolley and contact wire for ac and dc electric traction. RDSO, Ministry of Railways, India.

0.4 In the standard due to lack of data, hardness test (*see* **11.9**) has been kept under consideration. Details of this test will be added to the standard as soon as sufficient data is made available.

0.5 For the purpose of deciding whether a particular reqirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard covers the requirements for hard drawn trolley and grooved contact wire made from electrolytic tough pitch copper or cadmium copper alloy, used for electric-traction purposes.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 1885 (Part 32)-1971* shall apply.

3. MATERIAL

3.1 The wire shall be made from one of the following materials, as specified by the purchaser:

a) Electrolytic tough pitch copper of a composition satisfying the requirements of IS : 191 (Part 5)-1980†, and

b) Copper cadmium alloy with a cadmium content of 0·7 to 1·0 percent.

3.2 The wires shall satisfy the mechanical and electrical requirements given in Tables 1 and 2.

4. PHYSICAL CONSTANTS OF HARD-DRAWN COPPER

4.1 Volume Resistivity — The resistivity of hard-drawn high-conductivity copper is a function of the tensile strength. Within a range of 30-50 kg/mm² tensile strength, the following formula has been found to express sufficiently closely the results obtained in practice, and has been adopted in calculating the resistance specified in this standard:

$$P = \frac{T}{16}$$

where

P = Percentage increase in resistivity of the hard-drawn copper over its resistivity when annealed, and

T = tensile strength of the hard-drawn copper in kg/mm².

4.1.1 The resistances given in the tables are based on standard resistivity of annealed high-conductivity copper at 20°C, modified in accordance with the above formula.

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*Electrotechnical vocabulary: Part 32 Cables, conductors and accessories for electricity supply.

†Specification for copper (*third revision*).

TABLE 1 PROPERTIES OF HARD-DRAWN COPPER TROLLEY AND CONTACT WIRE

(*Clauses* 3.2, 6.4, 7.1, 7.2, 9.2, 11.4, 11.5, 11.6, 11.7 *and* 11.10)

Cross Sectional Area (1)	Standard Weight Per km (2)	Maximum Resistance Per km At 20°C (3)	Minimum Tensile Strength (4)	Conventional Limit of Elasticity *Min* (5)	Minimum Elongation in 200 mm (6)	Minimum Number of Bending (7)	Hardness (8)
mm²	kg	ohm	kg/mm²	kg/mm²	percent		
80	711·2	0·227 5	38·0	32·5	3	8	(Under consideration)
100	889·0	0·181 8	36·5	31·0	3	7	
107	951·2	0·169 9	36·5	31·0	3	7	
150	1333·5	0·121 2	36·5	31·0	3	6	
161	1431·0	0·112 5	33·0	—	3	6	
193	1715·8	0·093 6	31·0	—	4	5	

Note 1 — The values given in col 2 correspond to the standard cross sectional area of wire. The values given in col 3 corresponds to minimum cross sectional area (that is, 97 percent of the standard weight) and minimum specified tensile strength of the contact wire.

Note 2 — The conventional limit of elasticity indicated in col 5 is for information only. The conventional limit of elasticiy is defined as the maximum tensile load which the tensile test piece may withstand for a period of 10 seconds without undergoing a permanent elongation of more than 0·2 percent of the original gauge length (*see* **11.5**).

TABLE 2 PROPERTIES OF CADMIUM-COPPER TROLLEY AND CONTACT WIRE

(*Clauses* 3.2, 6.4, 7.1, 7.2, 9.2, 11.4, 11.5, 11.6, 11.7 *and* 11.10)

Cross Sectional Area (1) mm²	Standard Weight per km (2) kg	Maximum Resistance per km at 20°C (3) ohm	Minimum Tensile Strength (4) kg/mm²	Conventional Limit of Elasticity, *Min* (5) kg/mm²	Minimum Elongation in 200 mm (6) percent	Minimum Number of Bendings (7)	Hardness (8)
100	894·5	0·211 6	44	37·5	2·5	7	(Under consideration)
107	957·1	0·197 7	44	37·5	2·5	7	
150	1 342·0	0·141 1	44	37·5	2·5	6	

Note 1 — The values given in col 2 correspond to the standard cross sectional area of wire. The values given in col 3 correspond to minimum cross sectional area (that is, 97 percent of the standard weight) and minimum specified tensile strength of the contact wire.

Note 2 — The conventional limit of elasticity indicated in col 5 is for information only. The conventional limit of elasticity is defined as the maximum tensile load which the test piece may withstand for a period of 10 seconds without undergoing a permanent elongation of more than 0·2 percent of the original gauge length (*see* **11.5**).

At a temperature of 20°C, the volume resistivity of standard annealed copper is 1/58 = 0·017 241 ohm square millimetre per metre (ohm mm^2/m).

Copper which has a resistivity at 20°C of 1/58 = 0·017 247 ohm mm^2/m is said to have a conductivity of 100 percent.

4.2 Density — At a temperature of 20°C, the density of hard-drawn high-conductivity copper has been taken as 8·89 g/cm^3.

4.3 Coefficient of Linear Expansion — At a temperature of 20°C, the coefficient of linear expansion of hard-drawn high-conductivity copper has been taken as 0·000 017 per degree Celsius. The coefficient may be used over a temperature range from 0 to 150°C.

4.4 Constant Mass Temperature Coefficient of Resistance — At a temperature of 20°C, the coefficient of variation of resistance with temperature of hard-drawn high-conductivity copper, measured between two potential points rigidly fixed to the wire, the metal being allowed to expand freely, has been taken as 0·003 81 per degree Celsius, which is a representative value for copper of 97 percent conductivity.

5. PHYSICAL CONSTANTS OF HARD-DRAWN CADMIUM-COPPER

5.1 Volume Resistivity — At a temperature of 20°C, the resistivity of the hard-drawn cadmium-copper shall not exceed 0·020 525 ohm mm^2/m (84 percent conductivity).

5.2 Density — At a temperature of 20°C, the density of hard-drawn cadmium copper has been taken as 8·945 g/cm^3.

5.3 Coefficient of Linear Expansion — At a temperature of 20°C, the coefficient of linear expansion of hard-drawn cadmium-copper has been taken as 0·000 017 per degree Celsius. This coefficient may be used over a temperature range from 0 to 150°C.

5.4 Constant Mass Temperature Coefficient of Resistance — At a temperature of 20°C, the coefficient of variation of resistance with temperature of hard-drawn cadmium-copper, measured between two potential points rigidly fixed to the wire, the metal being allowed to expand freely, has been taken as 0·003 1 percent degree Celsius.

6. STANDARD SIZES, DIMENSIONS AND WEIGHTS

6.1 Standard Sizes — The standard sizes, shapes and dimensions of wire shall be as shown in Fig. 1, with the tolerances indicated therein.

6.2 Measurement of Diameter — The diameter of the grooved wire shall be measured in accordance with the method specified in **11.3.1.**

6.3 Checking of the Dimensions at the Bottom of the Groove — The dimensions at the bottom of the groove in the wire shall be checked in accordance with the method specified in **11.3.2**.

6.3.1 The dimensions for the different sizes of grooved wire are indicated in Fig. 1 and 2.

6.4 Standard Weights — The standard weight of the finished wire shall be calculated by the method specified in **11.4**. The value shall be as specified in Table 1 or Table 2 and shall be subjected to a tolerance of plus or minus 3 percent.

7. MECHANICAL AND ELECTRICAL PROPERTIES

7.1 The tensile strength, elongation and hardness, when tested in accordance with **11.5**, **11.6** and **11.9** shall not be less than the appropriate values given in Table 1 or Table 2. The wires shall also comply with the requirements of the bending test and the torsion test specified in **11.7** and **11.8**.

7.2 The electrical resistance per kilometre of the sample, multiplied by the appropriate constant in Table 3 or Table 4 and corrected for the cross sectional area, shall not exceed the maximum value given in Table 1 and Table 2.

8. FREEDOM FROM DEFECTS

8.1 The wire shall be clean, smooth and free from harmful defects, such as, scales, peelings, defects in the groove, etc.

8.2 The groove shall be uniform and free from twists. During the manufacture and winding of the wire on drums, every precaution shall be taken to avoid twisting of the wire.

9. JOINTS IN WIRES

9.1 There shall be no joints except those made in the soft rolled rod or wire before final drawing. Joints shall be as few as possible. Normally, these should be approximately 50 kg of material between two joints. The joints shall be made with high silver alloy conforming to classification BA Cu Ag 6 of IS : 2927-1975* or better methods may be used.

NOTE — It is recommended that the joints are carefully made under strict supervision and are periodically tested by the manufacturer. The joints shall be tested in the rod stage in accordance with IS : 9713-1981† for tensile, elongation, compression and surface defects.

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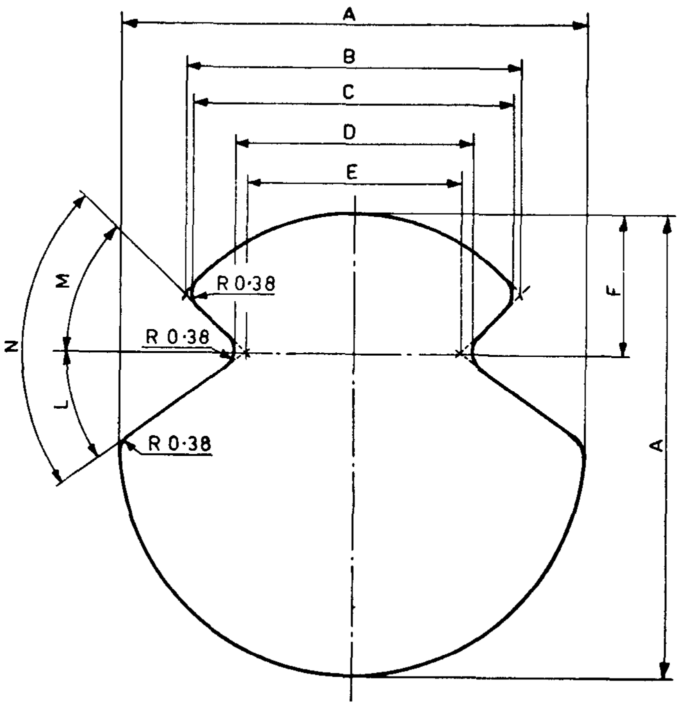
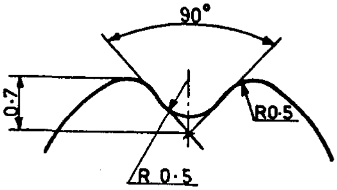
*Specification for brazing alloys (*first revision*).

†Specification for hot rolled electrolytic copper wire rods for electrical conductors (*first revision*).



Cross Section of Contact Wire	Linear Dimensions						Angular Dimensions		
	A	*B*	*C*	*D*	*E*	*F*	*L*	*M*	*N*
mm²	mm	mm	mm	mm	mm	mm	deg	deg	deg
90	10·60±0·14	—	—	5·60±0·20	5·10	3·93	27^{+1}_{-0}	51^{+1}_{-0}	78^{+2}_{-0}
100	12·00±0·16	—	—	5·60±0·20	5·10	4·13	27^{+1}_{-0}	51^{+1}_{-0}	78^{+2}_{-0}
107	12·24±0·16	—	—	6·92±0·15	6·50	4·43	27^{+1}_{-0}	51^{+1}_{-0}	78^{+2}_{-0}
150	14·50±0·20	—	—	6·92±0·15	6·50	4·00	27^{+1}_{-0}	51^{+1}_{-0}	78^{+2}_{-0}
161	15·00±0·15	12·2	12·00±0·25	$8·50^{+0·18}_{-0·30}$	8·10	5·75	27^{+2}_{-0}	51^{+1}_{-0}	78^{+3}_{-0}
193	16·40±0·15	12·2	12·00±0·25	$8·50^{+0·18}_{-0·30}$	8·10	5·3	27^{+2}_{-0}	51^{+1}_{-0}	78^{+3}_{-0}



Groove in the Case of a Cadmium-Copper Wire

A groove is provided over the whole length and in the top lobe of the cadmium-copper wire to make possible its distinction from a hard-drawn copper wire of the same section.

All dimensions in millimetres.

FIG. 1 SHAPE OF CONTACT WIRE

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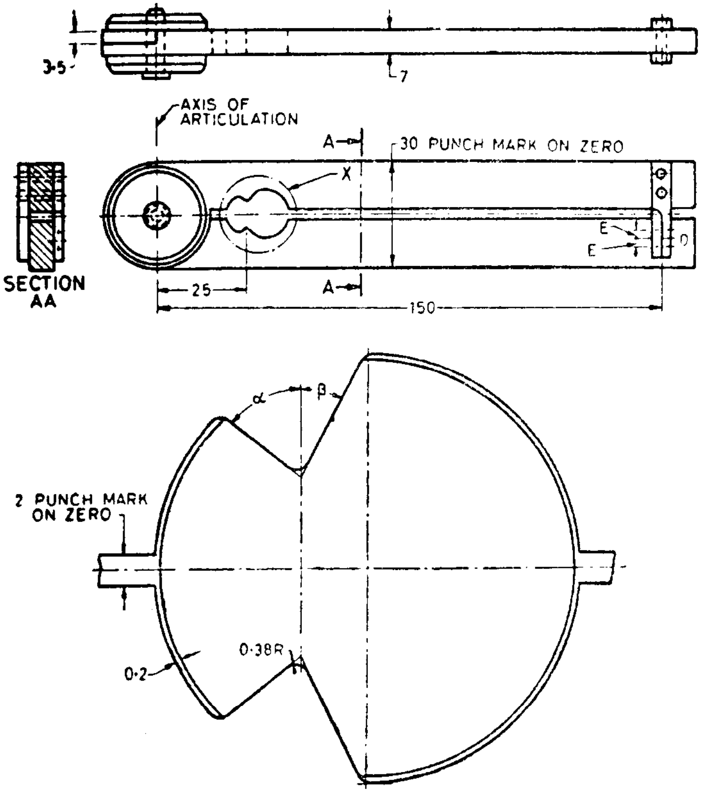

ENLARGED VIEW OF X

Size of Wire	Value of α	Value of β	Value of E_1	Value of E_2
mm²	deg	deg	mm	mm
80	51	27	1·2	1·2
100	51	27	1·2	1·2
107	51	27	0·9	0·9
150	51	27	0·9	0·9
161	51	27	1·1	1·8
193	51	27	1·1	1·8

All dimensions in millimetres.

Note — The tolerance on the measurement of angles is ± 5 minutes.

Fig. 2 Special Caliper for Checking Contact Wire

9.2 Joints, if made, shall comply with the requirements of tensile strength, elongation, hardness, bend test and electric resistance as given in Table 1 or Table 2 in the final stage of contact wire. These joints shall also be tested as in **11.8** for torsion test.

10. PACKING AND MARKING

10.1 The wire shall be supplied in different lengths as required by the purchaser, properly wound on drums; the turns of the wire being close and continuous without any overriding except on the first and last turns of each layer. The contact wire shall be wound on drums in such a way that the top (smaller) lobe of the contact wire shall be on the top. Each drum shall carry only one continuous length of wire.

10.1.1 The exact manufacturing lengths for thew ire shall be agreed to between the purchaser and the manufacturer. The lengths may vary between 500 and 2 000 metres.

10.1.2 No negative tolerance shall be permitted on the length of wire in any drum, the tolerance being checked after the test pieces required for the various tests have been cut.

10.2 The drums on which the wire is wound shall be 1 900 mm flange dia and 1 500 mm barrel dia and shall comply with IS : 1778-1980*.

10.3 The identification mark of the manufacturer shall be provided on the top lobe of the finished wire at a regular interval not exceeding 5 m in the letters of size not less than 5 mm by a rotating die. Drawing machine shall not be stopped for this purpose.

10.4 The following particulars shall be marked with indelible paint on the wire drums:

a) Order No. (purchaser's),
b) Size of wire,
c) Length of wire,
d) Gross and net weight,
e) Drum No., and
f) Other particulars as required by the purchaser, such as consignee.

10.5 The trolley and contact wire may also be marked with the Standard Mark.

NOTE — The use of the Standard Mark is governed by the provisions of the Bureau of Indian Standards Act 1986 and the Rules and Regulations made thereunder. The Standard Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by BIS and operated by the producer. Standard marked products are also continuously checked by BIS for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or processors, may be obtained from the Bureau of Indian Standards.

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*Specification for reels and drums for bare conductors (*first revision*).

11. TESTS

11.1 Classification of Tests

11.1.1 *Type Tests* — The following shall constitute the type tests:

a) Visual examination (*see* **11.2**),
b) Dimensional verification (*see* **11.3**),
c) Measurement of mass (*see* **11.4**),
d) Tensile test (*see* **11.5**),
e) Elongation test (*see* **11.6**),
f) Bending test (*see* **11.7**),
g) Torsion test (*see* **11.8**),
h) Hardness test (*see* **11.9**),
j) Electrical resistance test (*see* **11.10**), and
k) Chemical composition test (*see* **11.11**).

11.1.1.1 *Selection of samples* — Each test shall be done on 3 samples with joints and 3 samples without joints.

11.1.2 *Acceptance Tests* — All the tests specified under type tests (**11.1.1**) shall be carried out as acceptance tests.

11.1.2.1 *Selection of samples for tests and criteria for approval*

11.1.2.2 *Batches* — The contact wire shall be offered for inspection in batches of 6 drums, out of which three drums shall contain a joint for test near the outer end of the wire. These joints shall be representative of the joints in the batch and shall not have been made specifically for the testing purpose. This requirement could be met by a judicious division of the manufacturer's schedule of wire lengths.

One tests sample shall be cut from each drum in the presence of the inspector. No treatment shall be given to the samples before testing except that it may be straightened, if necessary.

11.1.2.3 *Samples without joints* — The three samples without joints shall be subjected to acceptance tests specified in **11.1.2**. The tests specified in **11.2**, **11.3**, **11.4**, **11.9** and **11.10** shall be done on all the three samples. Thereafter, one sample shall be subjected to the tests in **11.5** and **11.6**, and one sample to the tests in **11.7** and one to **11.8**. After destruction, one of the samples shall be subjected to chemical composition tests specified in **11.11**.

Should failure occur in more than one test, the batch shall be rejected. If any sample fails in any one test, a second sample of the wire shall be taken from the same drum from which the sample which failed was taken. This sample shall be subjected to the same test in which the original sample failed. If the sample passes the retest, the batch shall be deemed to have complied with the provisions of this clause. Should failure occur in retest, the batch shall be rejected.

11.1.2.4 *Samples with joints* — Three samples, each containing a joint representing the batch shall be subjected to the tests as mentioned in **11.1.2.3**. Should failure occur in more than one test, the batch shall be deemed to have been rejected. Should samples fail in any one test, a second joint shall be taken from the same drum from which the original sample was taken, and the test in which the first joint failed would be repeated. If the second joint passes the retest, the batch shall be deemed to have complied with the provisions of this clause.

NOTE — Where two successive joints have been tested on the same drum, the length of the wire on the drum would fall short of the ordered quantity. This short length may, however, be sealed in token of the acceptance and set aside until it could be conveniently supplied against subsequent order for a comparable length.

11.1.2.5 Batches which do not comply with **11.1.2.3** and **11.1.2.4** shall be rejected.

11.1.2.6 *Disposal of rejected wire* — Rejected wire shall be cut into pieces of length 300 m, or drawn again into thinner wire. This operation shall be conducted in the presence of an authorized representative of the purchaser.

11.1.2.7 *Test on wire rods* — Hot rolled wire rods shall be tested in accordance with IS : 9713-1981*. At least one sample shall be tested out of every 10 tonnes. In case wire bar is not hot rolled by the manufacturer at their works, the chemical composition as prescribed in type test, shall also be done as a routine test.

Records of these tests shall be maintained and given to the inspector at the time of acceptance tests.

The manufacturer shall test at least one joint, picked up at random out of every 50 joints made in the wire-rod stage by subjecting it to electrical resistance, tensile, and compression tests as per IS : 9713-1981*. Records of these tests results and the broken joints shall be checked by the inspector.

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*Specification for hot rolled electrolytic copper wire rods for electrical conductors (*first revision*).

11.1.3 *Routine Tests* — The following shall constitute the routine tests and shall be carried out on each drum:

a) Visual examination (*see* **11.2**),
b) Dimensional verification (*see* **11.3**),
c) Measurement of mass (*see* **11.4**),
d) Tensile test (*see* **11.5**), and
e) Elongation test (*see* **11.6**).

11.2 Visual Examination — The surface finish of contact wire and groove shall be checked for defects, such as, chips, scales, sharp edges, bubbles, peelings, scratches, pin holes, etc. The wire shall be checked visually for any twists or kinks.

11.3 Dimensional Verification

11.3.1 *Measurement of Diameter* — The diameter of the grooved wire shall be measured by means of a ratchet micrometer or a dial micrometer between two circular flat studs of a maximum diameter of 5 mm. The average value taken shall be the mean of two readings made in two perpendicular directions situated approximately in the same cross section.

11.3.2 *Checking of Dimensions at the Bottom of the Groove* — The dimensions at the bottom of the groove in the wire shall be checked by means of a special caliper made in accordance with Fig. 2 or by shadowgraph projection of not less than 10 magnification (the method of checking shall be subjected to agreement between the purchaser and the manufacturer).

11.4 Measurement of Mass — The mass of three samples of the contact wire, each of 10 cm length, which have passed the tests specified in **11.2** and **11.3**, shall be measured by weighing in a balance whose accuracy is 0·1 g or better. The calculated per kilometre weight of the wire shall meet the requirements specified in Tables 1 or 2.

11.5 Tensile Test — A test piece consisting of a straight length of wire shall be cut. The length of the test piece shall be such that when it is held in the jaws of the testing machine, the distance between the jaws is not less than 250 mm. A gauge length of 200 mm shall be marked on the test piece for the purpose of elongation test specified in **11.6**. If the sample contains a joint, it should be centrally in the gauge length. A testing machine whose accuracy may easily be checked shall be used and the machine shall be adjusted, if necessary. The load shall be applied gradually until the sample breaks. The rate of application of load shall be such that the rate of elongation of test piece per second does not exceed 5 percent of the distance between the jaws of the machine. The tensile strength of the wire shall be not less than the appropriate value specified in Table 1 or Table 2.

11.6 Elongation Test — The wire shall have an elongation, measured after fracture, of not less than the appropriate value specified in Table 1 or Table 2. The load shall be applied to straight lengths of wire having an original gauge length of 200 mm. The joint, if any, should be centrally in the gauge length. The extension shall be measured on the the gauge length after the fractured ends have been fitted together, provided that the fracture occurs between the gauge marks and not closer to either mark than one-quarter of the length between the gauge marks after fracture. If the fracture occurs outside this limit and the required elongation is not obtained, the test shall be disregarded and another test made. The test shall however, be valid, whatever the position of the fracture, if the required elongation is obtained.

11.7 Bending Test — The test consists of bending by hand a straight 200 mm length of wire through 90°C and back, alternately on either side of the vertical, so that the axes of the straight and bent portions of the wire remain in the same plane. The test piece shall be held in blocks of the type shown in Fig. 3 having a radius of 30 mm. Joint, if any, shall be centrally at the blocks so that it is subjected to bending. A tube closed at one end shall be slipped over the length of wire outside the blocks, the inside diameter of the tube being as close to the diameter of wire as possible. The lower end of the tube shall be 20 mm from the surface of the blocks. The first bending operation shall be carried out in such a direction that the top lobe of the wire is in tension. One bending shall be constructed as including all operations between two consecutive passages of the test piece through the vertical position. In each bending, the wire shall touch, over its whole length and in particular adjacent to the clamping plane, the face of the block towards which it is bent. Bending shall not be accompanied by any twisting of the wire. The rate of bending shall not exceed one bending per second. The test piece shall withstand, without fracturing completely, the appropriate number of bendings indicated in Table 1 and Table 2.

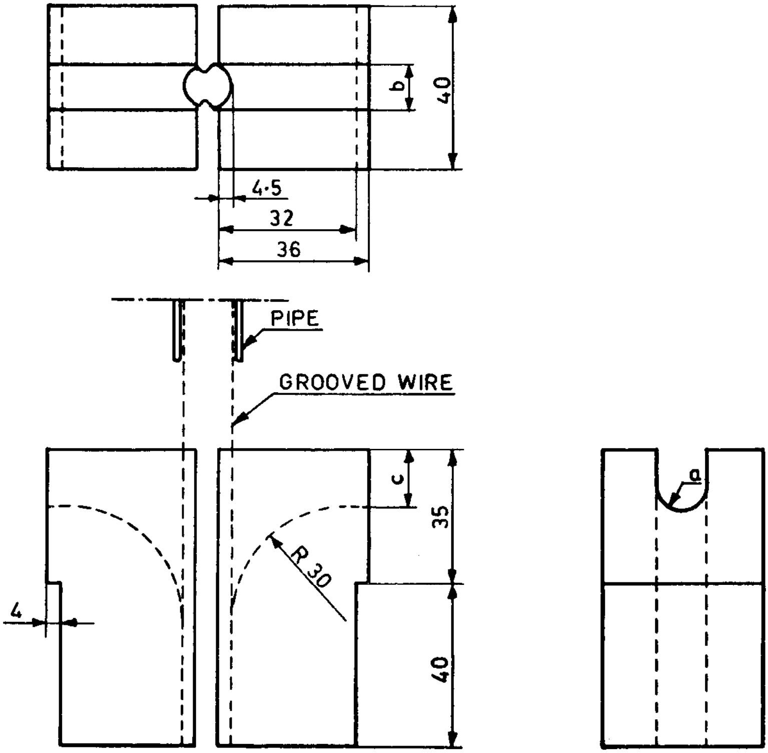
11.8 Torsion Test — The 300 mm sample wire shall be fixed on the torsion testing machine such that the distance between each grip and the joint if any, is 100 mm. The wire shall be fixed firmly to prevent it from rotating within the grips during the test. It shall then be subjected to torsion by:

a) rotating the movable grip through one complete revolution (360 degree),

b) bringing it back to the original mounted position by a complete turn in the opposite direction, and

c) rotating it once again through one complete turn in the same direction as in the first operation.

The three operations shall be completed in 30 to 45 seconds. On completion of this test, the sample shall not show any sign of rupture, crack or failure.



SIZE OF WIRE	*a*	*b*	*c*
mm^2	mm	mm	mm
80	6·5	13	15
100	6·5	13	15
107	6·5	13	15
150	7·65	15·3	18
161	7·9	15·8	18
193	8·5	17	18

All dimensions in millimetres.

FIG. 3 JAWS FOR BENDING TESTS

11.9 Hardness Test — Under consideration.

11.10 Electrical Resistance Test — The electric resistance of samples, with and without joints, shall be measured by double Kelvin Bridge Method. The current terminals shall be sufficiently away from the voltage terminals. The electrical resistance of test sample multiplied by $\frac{W \times C}{0{\cdot}97 \times K}$ shall not exceed the approprite maximum value in Table 1 and Table 2.

where

W = weight/km of test sample,

C = multiplier constant for temperature variation as per Table 3 and 4, and

K = standard weight per kilometre.

11.10.1 The measurement of resistance shall be carried out to an accuracy of at least one part of a thousand.

11.11 Chemical Composition — The chemical composition of the samples taken from the grooved contact wire of electrolytic copper, shall be tested for chemical composition in accordance with IS : 440-1964*. The composition shall conform to IS : 191 (Part 5)-1980†.

The chemical composition of contact wire of cadmium-copper shall be tested in accordance with IS : 3186-1965‡ to determine the cadmium content which should be within 0·7-1 0 percent. The chemical composition shall also be tested in accordance with IS : 440-1964* to determine the percentage of other metallic impurities, such as bismith, lead, arsenic, zinc, iron, antimony, etc. The impurities shall be within the permissible limits specified in IS : 191 (Part 5)-1980†.

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*Method of chemical analysis of copper (*revised*).

†Specification for copper (*third revision*).

‡Methods of chemical analysis of cadmium copper.

TABLE 3 MULTIPLIER CONSTANTS FOR HARD-DRAWN COPPER WIRE

(*Clauses* 7.2 *and* 11.10)

Constants for covering resistances at various temperatures to the standard temperature of 20°C, and reciprocals of the constants for converting resistance at 20°C to other temperatures.

TEMPERATURE (1)	MULTIPLIER CONSTANT (2)	RECIPROCAL OF CONSTANT (3)
°C		
5·0	1·060 6	0·942 9
5·5	1·058 5	0·944 8
6·0	1·056 3	0·946 7
6·5	1·054 2	0·948 6
7·0	1·052 1	0·950 5
7·5	1·050 0	0·952 4
8·0	1·047 9	0·954 3
8·5	1·045 8	0·956 2
9·0	1·043 7	0·958 1
9·5	1·041 7	0·960 0
10·0	1·039 6	0·961 9
10·5	1·037 6	0·963 8
11·0	1·035 5	0·965 7
11·5	1·033 5	0·967 6
12·0	1·031 4	0·969 5
12·5	1·029 4	0·971 4
13·0	1·027 4	0·973 3
13·5	1·025 4	0·975 2
14·0	1·023 4	0·977 1
14·5	1·021 4	0·979 0
15·0	1·019 4	0·981 0
15·5	1·017 4	0·982 9
16·0	1·015 5	0·984 8
16·5	1·013 5	0·986 7
17·0	1·011 6	0·988 6
17·5	1·009 6	0·990 5
18·0	1·007 7	0·992 4
18·5	1·005 7	0·994 3
19·0	1·003 8	0·996 2
19·5	1·001 9	0·998 1

(*Continued*)

TABLE 3 MULTIPLIER CONSTANTS FOR HARD-DRAWN COPPER WIRE — *Contd*

TEMPERATURE (1) °C	MULTIPLIER CONSTANT (2)	RECIPROCAL OF CONSTANT (3)
20·0	1·000 0	1·000 0
20·5	0·998 1	1·001 9
21·0	0·996 2	1·003 8
21·5	0·994 3	1·005 7
22·0	0·992 4	1·007 6
22·5	0·990 6	1·009 5
23·0	0·988 7	1·011 4
23·5	0·986 8	1 013 3
24·0	0·985 0	1·015 2
24·5	0·983 1	1·017 1
25·0	0·981 3	1·019 1
25·5	0·979 5	1·021 0
26·0	0·977 7	1·022 9
26·5	0·975 8	1·024 8
27·0	0·974 0	1·026 7
27 5	0·972 2	1·028 6
28·0	0·970 4	1·030 5
28·5	0·968 6	1·032 4
29·0	0·966 8	1·034 3
29·5	0·965 1	1·036 2
30·0	0·963 3	1·038 1

NOTE 1 — Given the resistance of a wire at *T*°*C*, the resistance at 20°C is found by multiplying the resistance at *T*°*C* by the constant for *T*°*C* given in col 2. Conversely, given the resistance at 20°C, the corresponding resistance at *T*°*C* is found by multiplying the resistance at 20°C by the reciprocal for *T*°*C*, given in col 3.

NOTE 2 — The temperature coefficient of resistance of copper varies slightly from sample to sample according to its exact conductivity. The figures given above are based on a coefficient of 0·003 81 per °C at 20°C, which is an average value for copper of 97 percent conductivity. The error in using this table for copper whithin the range of conductivity 96 to 98 percent will not exceed 0·06 percent.

TABLE 4 MULTIPLIER CONSTANTS FOR CADMIUM-COPPER WIRE

(*Clauses* 7.2 *and* 11.10)

Constants for converting resistances at various temperatures to the standard temperature of 20°C and reciprocals of the constants for converting resistance at 20°C to other temperatures.

TEMPERATURE	MULTIPLIER CONSTANT	RECIPROCAL OF CONSTANT
(1)	(2)	(3)
°C		
5·0	1·048 8	0·953 5
5·5	1·047 1	0·955 1
6·0	1·045 4	0·956 6
6·5	1·043 7	0·958 2
7·0	1·042 0	0·959 7
7·5	1·040 3	0·961 3
8·0	1·038 6	0·962 8
8·5	1·037 0	0·964 4
9·0	1·035 3	0·965 9
9·5	1·033 6	0·967 5
10·0	1·032 0	0·969 0
10·5	1·030 3	0·970 6
11·0	1·028 7	0·972 1
11·5	1·027 1	0·973 7
12·0	1·025 4	0·975 2
12·5	1·023 8	0·976 8
13·0	1·022 2	0·978 3
13·5	1·020 6	0·979 9
14·0	1·018 9	0·981 4
14·5	1·017 3	0·983 0
15·0	1·015 7	0·984 5
15·5	1·014 1	0·986 1
16·0	1·012 5	0·987 6
16·5	1·011 0	0·989 2
17·0	1·009 4	0·990 7
17·5	1·007 8	0·992 3
18·0	1·006 2	0·993 8
18·5	1·004 7	0·995 4
19·0	1·003 1	0·996 9
19·5	1·001 5	0·998 5

(*Continued*)

TABLE 4 MULTIPLIER CONSTANTS FOR CADMIUM-COPPER WIRE — *Contd*

TEMPERATURE (1) °C	MULTIPLIER CONSTANT (2)	RECIPROCAL OF CONSTANT (3)
20·0	1·000 0	1·000 0
20·5	0·998 4	1·001 6
21·0	0·996 9	1·003 1
21·5	0·995 4	1·004 7
22·0	0·993 8	1·006 2
22·5	0·992 3	1·007 8
23·0	0·990 8	1·009 3
23·5	0·989 3	1·010 9
24·0	0·987 7	1·012 4
24·5	0·986 2	1·014 0
25·0	0·984 7	1·015 5
25·5	0·983 2	1·017 1
26·0	0·981 7	1·018 6
26·5	0·980 2	1·020 2
27·0	0·978 8	1·021 7
27·5	0·977 3	1·023 3
28·0	0·975 8	1·024 8
28·5	0·974 3	1·026 4
29·0	0·972 8	1·027 9
29·5	0·971 3	1·029 5
30·0	0·969 9	1·031 0

NOTE 1 — Given the resistance of a wire at *T*°*C*, the resistance at 20°C is found by multiplying the resistance at *T*°*C* by the constant for *T*°*C*, given in col 2. Conversely, given the resistance at 20°C, the corresponding resistance at *T*°*C* is found by multiplying the resistance at 20°C by the reciprocal for *T*°*C*, given in col 3.

NOTE 2 — The temperature resistance coefficients of a large number of samples of cadmium-copper complying with the requirements of this standard have been found to vary between 0·003 1 and 0·003 5 per degree Celsius. There is some evidence to suggest that the coefficients of copper alloys in general are directly proportional to their conductivities. It is concluded that the difference in conductivity between cadmium-copper as contact wire and as strand wire is not sufficient to justify a difference in agreed temperature resistance coefficient.

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